CLAIMS

1. A system for sintering a quartz tube, said quartz tube having a cylindrical wall defining an annular space and an outer layer of silica soot deposited on an outer surface thereof, said system comprising:

a) a furnace for heating said quartz tube to a temperature of at least 1400°C in a controlled atmosphere, said furnace having a heating zone in which said quartz tube is sintered;

b) a support rod assembly disposable in said annular space, said support rod assembly comprising: (i) a cylindrical support rod having a central portion, said central portion having a surface roughness of from about 0.1 micron to about 4 microns, wherein said central portion has an ovality of up to about 0.5 mm and a bow of up to about 0.7 mm/m along a longitudinal axis of said support rod assembly, wherein said cylindrical support rod has a coefficient of thermal expansion that is greater than a coefficient of thermal expansion of said quartz tube, wherein said support rod assembly is substantially chemically inert with respect to silica in an atmosphere comprising an inert gas and at least one of fluorine, chlorine, and combinations thereof at temperatures of at least 1400°C, and wherein said support rod assembly straightens and supports said quartz tube and prevents tapering of said inner diameter due to creep; and (ii) at least one retaining portion coupled to said at least one end of said cylindrical support rod for preventing slippage of said quartz tube from said support rod assembly; and

c) means for positioning said support rod assembly and said quartz tube within said heating zone.

2. The system according to Claim 2, wherein said central portion has an ovality of up to about 0.5 mm and a bow of up to about 0.7 mm/m along a longitudinal axis of said cylindrical support rod.

3. The system according to Claim 1, wherein said central portion comprises a carbonaceous material.

4. The system according to Claim 3, wherein said carbonaceous material comprises graphite.

5. The system according to Claim 4, wherein said graphite has been purified in the presence of chlorine gas.

6. The system according to Claim 4, wherein said central portion further includes a coating disposed on an outer surface of said central portion, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

7. The system according to Claim 3, wherein said graphite has an ash content of less than 100 parts per million.

8. The system according to Claim 1, wherein said central portion comprises a cylindrical alumina core and a coating disposed on an outer surface of said cylindrical alumina core, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

9. The system according to Claim 1, wherein said central portion comprises a tubular structure.

10. The system according to Claim 1, wherein said central portion comprises a solid rod.

11. The system according to Claim 1, wherein said central portion has an outer diameter from about 15 mm to about 50 mm.

12. The system according to Claim 1, wherein said central portion has a has an length from about 750 mm to about 1500 mm.

13. The system according to Claim 1, wherein said quartz tube has an inner diameter and said central portion has an outer diameter, and wherein said inner diameter differs from said outer diameter by up to about 0.1 mm over the length of said central portion.

14. The system according to Claim 1, wherein said at least one retaining portion comprises a coupling for engaging said means for positioning and at least one of a first end of said quartz tube and an end of said cylindrical support rod.

15. The system according to Claim 14, further including a second retaining portion affixed to a second end of said cylindrical support rod and distal to said coupling.

16. The system according to Claim 1, wherein said positioning means comprises a rod, wherein said rod is one of a quartz rod and a graphite rod, and wherein said positioning means is coupled to an external support structure.

17. The system according to Claim 16, wherein said positioning means further includes a drive system coupled to said rod, wherein said drive system is capable of moving said quartz tube and said support rod assembly through said furnace.

18. The system according to Claim 1, wherein said positioning means comprises a drive mechanism coupled to said furnace, wherein said drive mechanism is capable of moving said furnace relative to a longitudinal axis of said quartz tube.

19. The system according to Claim 1, wherein said system is adapted to sinter a quartz fiber optic sleeve tube.

20. The system according to Claim 1, wherein said controlled atmosphere comprises helium and at least one of and chlorine, fluorine, and combinations thereof.

21. A support rod assembly for supporting a quartz tube during sintering, said support rod assembly comprising:

a) a cylindrical support rod having a central portion, said central portion comprising a carbonaceous material and having a surface roughness of from about 0.1 micron to about 4 microns, wherein said central portion has an ovality of up to about 0.5 mm and a bow of up to about 0.7 mm/m along a longitudinal axis of said support rod assembly, wherein said central portion straightens and supports said

quartz tube and prevents tapering of said inner diameter due to creep, and wherein said cylindrical support rod has a coefficient of thermal expansion that is greater than a coefficient of thermal expansion of said quartz tube and is substantially chemically inert with respect to silica in an atmosphere comprising an inert gas and at least one of fluorine, chlorine, and combinations thereof at temperatures of at least 1400°C; and

b) at least one retaining portion coupled to said at least one end of said cylindrical support rod for preventing slippage of said quartz tube from said support rod assembly.

22. The support rod according to Claim 21, wherein said carbonaceous material comprises graphite.

23. The support rod according to Claim 22, wherein said graphite has been purified in the presence of chlorine gas.

24. The support rod according to Claim 22, wherein said graphite has an ash content of up to about 100 parts per million.

25. The support rod assembly according to Claim 21, wherein said cylindrical support rod further includes a coating disposed on an outer surface of said central portion, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

26. The support rod assembly according to Claim 21, wherein said central portion comprises a tubular structure.

27. The support rod assembly according to Claim 21, wherein said central portion comprises a solid rod.

28. The support rod assembly according to Claim 21, wherein said central portion comprises a cylindrical alumina core and a coating disposed on an outer surface of said cylindrical alumina core, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

29. The system according to Claim 21, wherein said central portion has an outer diameter from about 15 mm to about 50 mm.

30. The system according to Claim 21, wherein said central portion has a length from about 750 mm to about 1500 mm.

31. The system according to Claim 21, wherein said quartz tube has an inner diameter and said central portion has an outer diameter, and wherein said inner diameter differs from said outer diameter by up to about 0.1 mm over the length of said central portion.

32. The support rod assembly according to Claim 21, wherein said at least one retaining portion comprises:

a) a first retaining portion affixed to a top end of said cylindrical support rod, wherein said first retaining portion engages at least one of a top end of said quartz tube and a top end of said cylindrical support rod, and wherein said first retaining portion prevents said quartz tube from slipping downward; and

b) a second retaining portion coupled to a bottom end of said cylindrical support rod for preventing said quartz tube from slipping off said support rod assembly.

33. The support rod assembly according to Claim 21, wherein said atmosphere comprises helium and chlorine.

34. A system for sintering a quartz fiber optic sleeve tube, said system comprising:

a) a furnace for heating said quartz tube to a temperature of at least 1400°C in a controlled atmosphere, said furnace having a heating zone in which said quartz tube is sintered;

b) a support rod assembly for supporting said quartz tube during sintering, said support rod assembly comprising: (i) a cylindrical support rod having a central portion, said central portion comprising a carbonaceous material and having a

surface roughness of from about 0.1 micron to about 4 microns, wherein said central portion has an ovality of up to about 0.5 mm and a bow of up to about 0.7 mm/m along a longitudinal axis of said support rod assembly, wherein said central portion straightens and supports said quartz tube and prevents tapering of said inner diameter due to creep, and wherein said cylindrical support rod has a coefficient of thermal expansion that is greater than a coefficient of thermal expansion of said quartz tube and is substantially chemically inert with respect to silica in an atmosphere comprising an inert gas and at least one of fluorine, chlorine, and combinations thereof at temperatures of at least 1400°C; and (ii) at least one retaining portion coupled to said at least one end of said cylindrical support rod for preventing slippage of said quartz tube from said support rod assembly; and

c) means for positioning said support rod assembly and said quartz tube within said heating zone.

35. The system according to Claim 34, wherein said carbonaceous material comprises graphite.

36. The system according to Claim 35, wherein said graphite has an ash content of up to about 100 parts per million.

37. The system according to Claim 34, wherein said graphite has been purified in the presence of chlorine gas.

38. The system according to Claim 34, wherein said central portion further includes a coating disposed on an outer surface of said central portion, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

39. The system according to Claim 34, wherein said cylindrical support rod comprises a cylindrical alumina core and a coating disposed on an outer surface of said cylindrical alumina core, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

40. The system according to Claim 34, wherein said central portion comprises a tubular structure.

41. The system according to Claim 34, wherein said central portion comprises a solid rod.

42. The system according to Claim 34, wherein said central portion has an outer diameter from about 15 mm to about 50 mm.

43. The system according to Claim 34, wherein said central portion has a has a length from about 750 mm to about 1500 mm.

44. The system according to Claim 34, wherein said quartz tube has an inner diameter and said central portion has an outer diameter, and wherein said inner diameter differs from said outer diameter by up to about 0.1 mm over the length of said central portion.

45. The system according to Claim 34, wherein said at least one retaining portion comprises:

a) a first retaining portion affixed to a top end of said cylindrical support rod, wherein said first retaining portion engages at least one of a top end of said quartz tube and a top end of said cylindrical support rod, and wherein said first retaining portion prevents said quartz tube from slipping downward; and

b) a second retaining portion coupled to a bottom end of said cylindrical support rod for preventing said quartz tube from slipping off said support rod assembly.

46. The system according to Claim 34, wherein said positioning means comprises a rod, wherein said rod is one of a quartz rod and a graphite rod, and wherein said positioning means is coupled to an external support structure.

47. The system according to Claim 34, wherein said positioning means further include a drive system coupled to said rod, wherein said drive system is

capable of moving said quartz tube and said support rod assembly through said furnace.

48. The system according to Claim 34, wherein said positioning means comprises a drive mechanism coupled to said furnace, wherein said drive mechanism is capable of moving said furnace relative to a longitudinal axis of said quartz tube.

49. The system according to Claim 21, wherein said atmosphere comprises helium and at least one of and chlorine, fluorine, and combinations thereof.

50. A method of making a quartz fiber optic sleeve tube, the method comprising the steps of:

a) providing a quartz tube, the quartz tube having a cylindrical wall defining an annular space and an outer layer of silica soot deposited on an outer surface thereof;

b) providing a cylindrical support rod, wherein the cylindrical support rod has an ovality of up to about 0.5 mm and has a bow of less than about of up to about 0.7 mm/m along its longitudinal axis, and wherein the cylindrical support rod has a coefficient of thermal expansion greater than a coefficient of thermal expansion of the quartz tube, and has a surface roughness of from about 0.1 micron to about 4 microns;

c) disposing the cylindrical support rod in the annular space of the quartz tube; and

d) consolidating the outer layer of silica soot and the quartz tube at a first temperature, wherein the cylindrical support rod supports the quartz tube at the first temperature, and wherein consolidating the outer layer of silica soot and the quartz tube at the first temperature forms the fiber optic sleeve tube.

51. The method according to Claim 50, further comprising the step of removing the cylindrical support rod from the annular space following the step of consolidating the outer layer of silica soot and the quartz tube at a first temperature.

52. The method according to Claim 50, wherein the first temperature is in a range from about 1450°C to about 1550°C.

53. The method according to Claim 50, wherein the cylindrical support rod comprises a carbonaceous material.

54. The method according to Claim 50, wherein the cylindrical support rod comprises graphite.

55. The method according to Claim 50, wherein the cylindrical support rod further comprises a coating disposed on an outer surface of the cylindrical support rod, wherein the coating comprises at least one of graphite, amorphous carbon, and boron nitride.

56. A quartz fiber optic sleeve tube, said quartz fiber optic sleeve tube comprising a cylindrical wall defining an annular space therein, said cylindrical wall being substantially parallel to a longitudinal axis, wherein said annular space has an ovality of up to about 0.5 mm and said quartz fiber optic sleeve tube has a bow of less than about of up to about 0.7 mm/m along said longitudinal axis, and wherein said quartz fiber optic sleeve tube is formed by:

a) providing a quartz tube, said quartz tube having a cylindrical wall defining an annular space and an outer layer of silica soot deposited on an outer surface thereof;

b) providing a cylindrical support rod, wherein said cylindrical support rod has a coefficient of thermal expansion that is greater than a coefficient of thermal expansion of said quartz tube, is substantially chemically inert with respect to silica in an atmosphere comprising an inert gas and at least one of fluorine, chlorine, and combinations thereof at temperatures of at least about 1400°C, has a surface roughness of from about 0.1 micron to about 4 microns, and has a bow of less than about of up to about 0.7 mm/m along said longitudinal axis;

c) disposing said cylindrical support rod in said annular space of said quartz tube; and

d) consolidating said outer layer of silica soot and said quartz tube at a first temperature, wherein said cylindrical support rod supports said quartz tube at said first temperature, and wherein and consolidating said outer layer of silica soot and the quartz tube at said first temperature forms said fiber optic sleeve tube.

57. A mandrel assembly for fabricating a quartz fiber optic sleeve tube, said mandrel assembly comprising:

a) a quartz tube, said quartz tube having a cylindrical wall defining an annular space and an outer layer of silica soot deposited on an outer surface thereof; and

b) a cylindrical support rod disposed in said annular space, wherein said cylindrical support rod has a coefficient of thermal expansion that is greater than a coefficient of thermal expansion of said quartz tube, is substantially chemically inert with respect to silica in an atmosphere comprising an inert gas and at least one of fluorine, chlorine, and combinations thereof at temperatures of at least 1400°C, and has a surface roughness of from about 0.1 micron to about 4 microns, and wherein said cylindrical support rod straightens and supports said quartz tube and prevents tapering of said inner diameter due to creep.

58. The mandrel assembly according to Claim 57, wherein said cylindrical support rod has an ovality of up to about 0. 5 mm and has a bow of up to about 0.7 mm/m along a longitudinal axis of said cylindrical support rod.

59. The mandrel assembly according to Claim 57, wherein said cylindrical support rod comprises a carbonaceous material.

60. The mandrel assembly according to Claim 59, wherein said carbonaceous material comprises graphite.

61. The mandrel assembly according to Claim 60, wherein said graphite has been purified in the presence of chlorine gas.

62. The mandrel assembly according to Claim 60, wherein said graphite has an ash content of less than 100 parts per million.

63. The mandrel assembly according to Claim 60, wherein said cylindrical support rod further includes a coating disposed on an outer surface of said cylindrical support rod, wherein said coating comprises at least one of graphite deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

64. The mandrel assembly according to Claim 57, wherein said cylindrical support rod comprises a cylindrical alumina core and a coating disposed on an outer surface of said cylindrical alumina core, wherein said coating comprises at least one of graphite, wherein said graphite is deposited by chemical vapor deposition, amorphous carbon, and boron nitride.

65. The mandrel assembly according to Claim 57, wherein said outer layer comprises a central portion having an outer surface that is substantially parallel to said cylindrical wall of said quartz tube and a central portion length, wherein said cylindrical support rod provides support to said quartz tube along said central portion length.

66. The mandrel assembly according to Claim 65, wherein said cylindrical support rod has a rod length that is a least as long as said central portion length.

67. The mandrel assembly according to Claim 57, wherein said quartz tube has an inner diameter from about 15 mm to about 55 mm.

68. The mandrel assembly according to Claim 67, wherein said quartz tube has an inner diameter from about 18 mm to about 30 mm.

69. The mandrel assembly according to Claim 57, wherein said quartz tube has an inner diameter and said cylindrical support rod has an outer diameter, and wherein said inner diameter differs from said outer diameter by up to about 0.1 mm over the length of said cylindrical support rod.

70. The mandrel assembly according to Claim 57, wherein said central portion comprises a tubular structure.

71. The mandrel assembly according to Claim 57, wherein said central portion comprises a solid rod.